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High-Performance Liquid Chromatography (HPLC) Measurements of Phytoplankton Pigment Distributions of Ocean Waters

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<p>Until the application of high-performance liquid chromatography (HPLC) to phytoplankton pigment analysis, it was difficult to quantitatively measure these pigment compounds. HPLC, the state-of-the-art method for the separation and quantification of photosynthetic pigments, is detailed in this report. HPLC reduces interferences caused by overlapping absorption and fluorescence bands of various pigments. HPLC-derived pigment distributions were measured in the upper 200 meters during two NOSC-sponsored cruises on the USNS LYNCH on 1-22 August 1986 and 29 July - 18 August 1987 in the Norwegian, Barents, and Greenland Seas.</p>					
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High-Performance Liquid Chromatography (HPLC) Measurements of Phytoplankton Pigment Distributions of Ocean Waters

Norwegian, Barents and Greenland Seas - 1 August - 22 August 1986
Norwegian and Greenland Seas - 29 July - 18 August 1987

Charles C. Trees

1.0 INTRODUCTION

Particulates, especially phytoplankton, significantly affect ocean optical properties by absorbing and scattering light and it is the various suite of pigments (chlorophylls, carotenoids, phycobilins) present within the phytoplankton that contribute most to the attenuation of light. In coastal areas, where dissolved organic material and inorganic particulate concentrations are high, pigments have a reduced influence on the optical properties. The general absorption by the major algal pigments and the major windows of clarity in the water spectrum are shown in Figure 1. Chlorophylls (*a*, *b* and *c*) and some carotenoids (xanthophyll and carotene) have absorption maxima between 425-450 nm and from 525-575 nm for other carotenoids (fucoxanthin and peridinin) and phycoerthrins (red and blue-green algal). Between 525-650 nm another blue-green algal pigment, phycocyanin, has a maximum absorption peak. The spectra for the chlorophyll degradation products (chlorophyllides, phaeophorbides and phaeophytins) which are not shown in Figure 1 have similar absorption maxima as their associated chlorophylls.

Until the application of high-performance liquid chromatography (HPLC) to phytoplankton pigment analysis, it was difficult to quantitatively measure these various pigment compounds. HPLC is the state of the art method for the separation and quan-

ification of photosynthetic pigments and recent investigations (Gieskes and Kray, 1983; Bidigare *et al.*, 1986; Trees *et al.*, 1986) have demonstrated that HPLC methods can be routinely used for phytoplankton pigment analysis. The use of HPLC minimizes the interferences caused by overlapping absorption and fluorescence bands of the various pigments, since the pig-

ments are physically separated on the column and individually quantified by absorption and/or fluorescence detectors (Trees *et al.*, 1985).

HPLC derived pigments distributions were measured in the upper 200

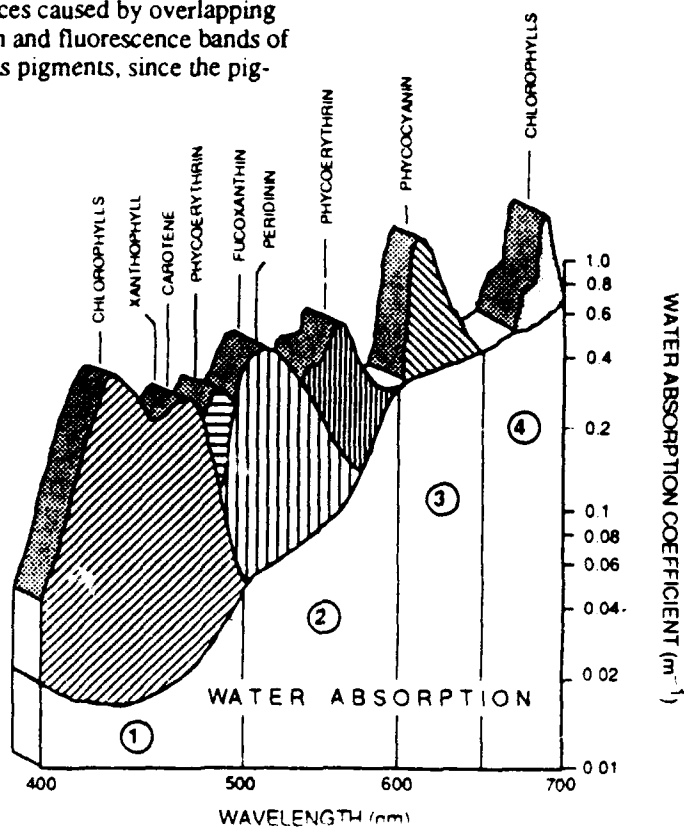


Figure 1. Relative pigment absorption of 18 nm bands of water clarity (Fensholt, 1983).

meters by the Visibility Laboratory during two cruises on the USNS Lynch (1-22 August 1986 and 29 July - 18 August 1987) in the Norwegian, Barents and Greenland Seas. Optical variability (see VisLab EN-015-86t and OcOp-88t-001) was determined by deploying spectral radiometers and towing a self-contained, depth-undulating oceanographic recorder (UOR). This UOR measured depth, temperature, *in vivo* fluorescence, up- and downwelling hemispherical scalar irradiance and cosine irradiance at 450, 488 and 550 nm during its undulations between 5 and 50 meters (Aiken, and Bellan, 1986). Continuous sub-surface temperature and *in vivo* fluorescence was also measured from water pumped from the shipboard sea chest (2-3 meters). During transects between stations, discrete water samples were drawn from this pumping system for HPLC analysis. In addition AVHRRK sea surface temperature data was acquired from a receiving station at the University of Dundee, Scotland, and processed into sea surface temperature (SST) imagery. Cruise tracks and station locations for the two cruises are shown in Figures 2 and 3 and summarized in Tables 1 and 2.

2.0 HPLC METHODS AND INSTRUMENTATION

Hydrocasts were performed at most of the stations using a General Oceanics rosette sampler/Neil-Brown CTD system, equipped with twelve 1.5 liter Niskin bottles. Water samples for pigment analyses were drawn from the bottles which were spaced throughout the water column based on transmissometry and fluorescence profiles. At least one bottle was tripped within the particle and phytoplankton biomass maxima. Samples were then filtered through 0.4 μ m Nuclepore polyester membrane filters and either frozen in liquid nitrogen for HPLC processing on return to the Visibility Laboratory (1986 cruise) or extracted and analyzed on board the ship (1987 cruise). The extraction solvent varied between cruises in that 90% acetone was used for August 1986 cruise; whereas, a 40:60% solution of dimethyl sulfoxide (DMSO) and 90% acetone was selected for the 1987 cruise. The advantage of the latter solvent is its enhanced pigment extraction efficiencies for cyanobacteria and green algae.

The HPLC system shown in Figure 4 consisted of a Spectra Physics Extended Range Pump (SP-8700XR) and Organizer Module-Dynamic Mixer (SP-8750) equipped with a reverse-phase Radial-PAK C₁₈ column (10 μ m particle size, Waters Associates) and 500 μ l sample loop. To facilitate the separation of the dephytylated pigments (chlorophyllide *a*, phaeophorbide *a* and chlorophyll *c*) samples were mixed prior to injection with an ion

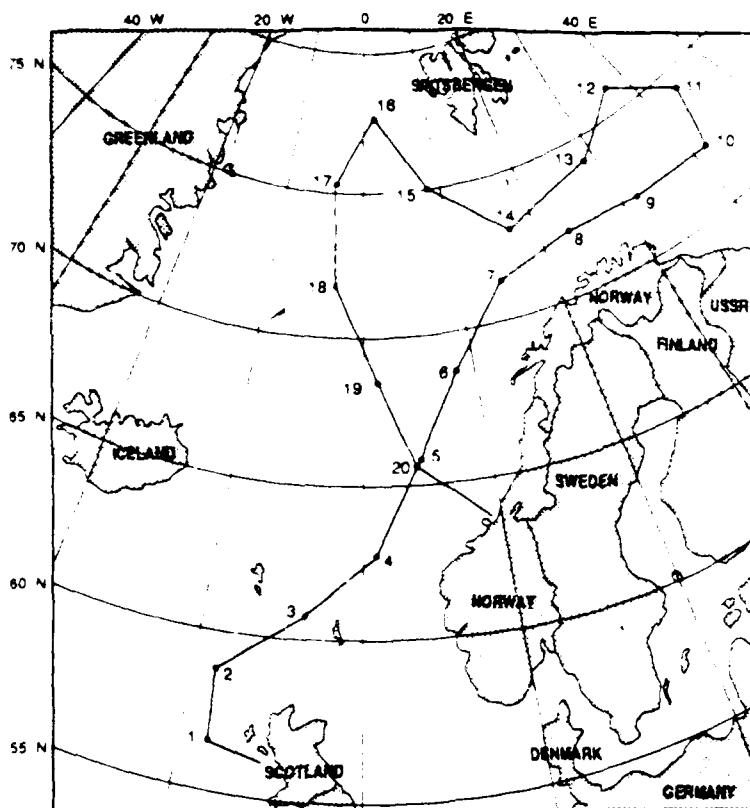


Figure 2. Cruise track and station locations during NOSC cruise in the Norwegian, Barents and Greenland Seas (1-22 August 1986).

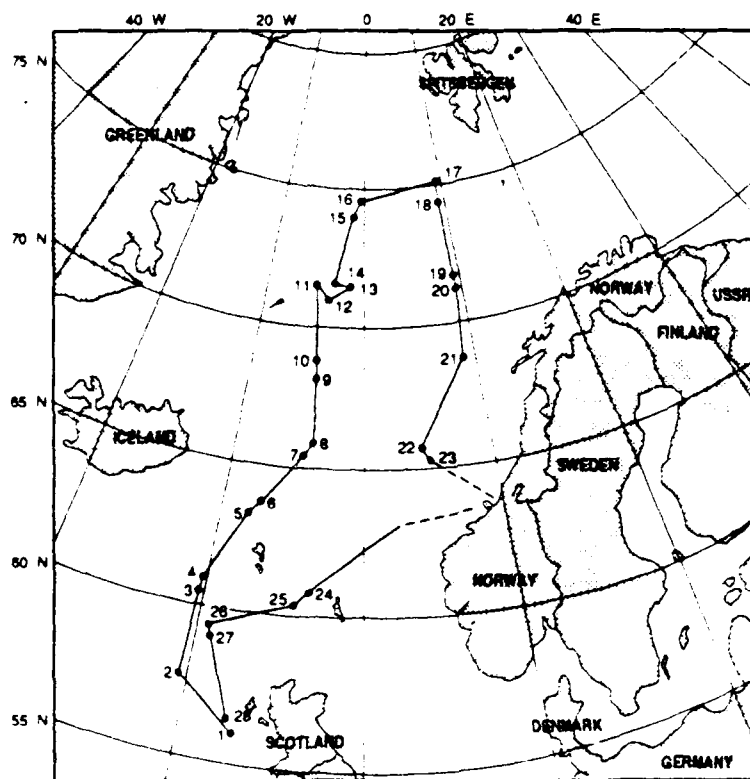


Figure 3. Cruise track and station locations during NOSC cruise and follow-up cruise in the Norwegian, Barents and Greenland Seas (29 July - 18 August 1987).

pairing solution of tetrabutylammonium acetate and ammonium acetate (Mantoura and Llewellyn, 1983). Pigments were separated on the column using a two solvent system [A-(80:10:10; methanol:ion-pairing solution:distilled water) and B-(100% methanol)]. Solvent A was pumped for three minutes followed by a linear gradient elution to 100% B in 9 minutes and then held at 100% B for 8 more minutes. At a flow rate of 10 ml min⁻¹ the separation of the various pigments required 20 minutes. As the various chlorophylls and carotenoids were eluted off the column their peaks were measured using absorption (Waters Associates Model 440 Single Channel Absorbance Detector equipped with a 436 nm filter assembly) and fluorescence detectors (Turner Designs Model 10 equipped with a liquid chromatography cell or Kratos FS-950 Fluoromat). A sample chromatogram using this method is shown in Figure 5. The outputs from the detectors were recorded on a Spectra Physics Two Channel Computing Integrator (SP-4270) and pigment concentrations were calculated from calibration tables (concentration per peak height or area) which were prepared from pigment standards.

3.0 DATA

The HPLC derived pigment concentrations for both cruises are listed in Appendices A, B, C and D. Nine pigment compounds were identified and quantified from the chromatograms. The continuous *in vivo* fluorescence and temperature for the August 1986 cruise is shown in Figure 6; whereas, the 1987 data from the continuous monitoring system is contained in OcOp-88t-001.

4.0 DATA ANALYSIS

Only a preliminary analysis of the HPLC derived pigment, optical and remote sensing data has been completed. A brief review of these results, focusing on vertical and horizontal bio-optical measurements across the Arctic Front during the 1986 cruise, will be given.

The circulation of the Greenland Sea is characterized by a cyclonic (counterclockwise) gyre with a strong western boundary current. Its southern extent is limited by the Jan Mayen and East Icelandic Currents; whereas, the northern flow is centered near the Mohns Ridge and merges with the West Spitsbergen Current (Figure 7). Along the Jan Mayen and East Greenland Currents two permanent fronts occur, the East Greenland Polar Front and the Arctic Front. Using nomenclature proposed by Swift (1986), these frontal systems divide the area into three hydrographic regions (the polar domain, the region west of the East Greenland Polar Front which has direct polar influence, the Atlantic domain, the region east of the

Table 1. Station Locations for USNS Lynch Cruise (1-22 August 1986)

Date	Station	Latitude	Longitude
2 Aug 86	1	56° 36.1' N	8° 34.5' W
3 Aug 86	2	58° 43.8' N	8° 42.9' W
4 Aug 86	3	60° 43.6' N	3° 58.6' W
5 Aug 86	4	62° 48.4' N	0° 54.8' E
6 Aug 86	5	65° 43.4' N	4° 10.8' E
7 Aug 86	6	68° 42.6' N	8° 16.2' E
8 Aug 86	7	71° 23.4' N	14° 09.6' E
9 Aug 86	8	72° 15.9' N	23° 01.2' E
10 Aug 86	9	72° 18.2' N	31° 52.4' E
11 Aug 86	10	72° 19.6' N	41° 35.6' E
12 Aug 86	11	74° 41.9' N	44° 31.7' E
13 Aug 86	12	76° 00.6' N	37° 06.3' E
14 Aug 86	13	74° 17.3' N	29° 09.8' E
15 Aug 86	14	73° 06.0' N	16° 56.9' E
16 Aug 86	15	75° 05.2' N	8° 17.2' E
17 Aug 86	16	77° 44.2' N	1° 38.4' E
18 Aug 86	17	75° 19.2' N	3° 58.5' W
19 Aug 86	18	71° 51.7' N	3° 07.1' W
20 Aug 86	19	68° 30.3' N	1° 04.0' E
21 Aug 86	20	65° 42.1' N	4° 10.2' E

Table 2. Station Locations for USNS Lynch Cruise (29 July - 18 August 1987)

Date	Station	Latitude	Longitude
31 Jul 87	1	55° 57.6' N	7° 25.2' W
1 Aug 87	2	57° 56.0' N	10° 50.0' W
2 Aug 87	3	60° 26.7' N	10° 55.5' W
2 Aug 87	4	60° 55.0' N	11° 03.9' W
3 Aug 87	5	63° 05.4' N	8° 03.5' W
3 Aug 87	6	63° 24.1' N	7° 39.5' W
4 Aug 87	7	65° 32.0' N	4° 50.8' W
4 Aug 87	8	65° 55.5' N	4° 21.3' W
5 Aug 87	9	68° 16.5' N	4° 25.1' W
5 Aug 87	10	68° 46.4' N	4° 32.5' W
6 Aug 87	11	71° 27.1' N	4° 53.5' W
6 Aug 87	12	70° 53.2' N	3° 36.2' W
7 Aug 87	13	71° 33.2' N	1° 50.4' W
7 Aug 87	14	71° 28.4' N	3° 31.0' W
8 Aug 87	15	74° 06.9' N	1° 29.6' W
8 Aug 87	16	74° 36.8' N	1° 05.6' W
9 Aug 87	17	75° 04.7' N	8° 13.3' E
9 Aug 87	18	74° 35.7' N	8° 05.5' E
10 Aug 87	19	71° 44.9' N	8° 18.1' E
10 Aug 87	20	71° 12.6' N	8° 21.2' E
11 Aug 87	21	68° 42.7' N	8° 15.5' E
12 Aug 87	22	65° 43.1' N	4° 10.0' E
12 Aug 87	23	65° 32.8' N	4° 41.9' E
15 Aug 87	24	60° 43.5' N	3° 58.6' W
15 Aug 87	25	60° 28.1' N	4° 35.2' W
16 Aug 87	26	59° 20.1' N	9° 30.1' W
16 Aug 87	27	59° 00.6' N	9° 21.7' W

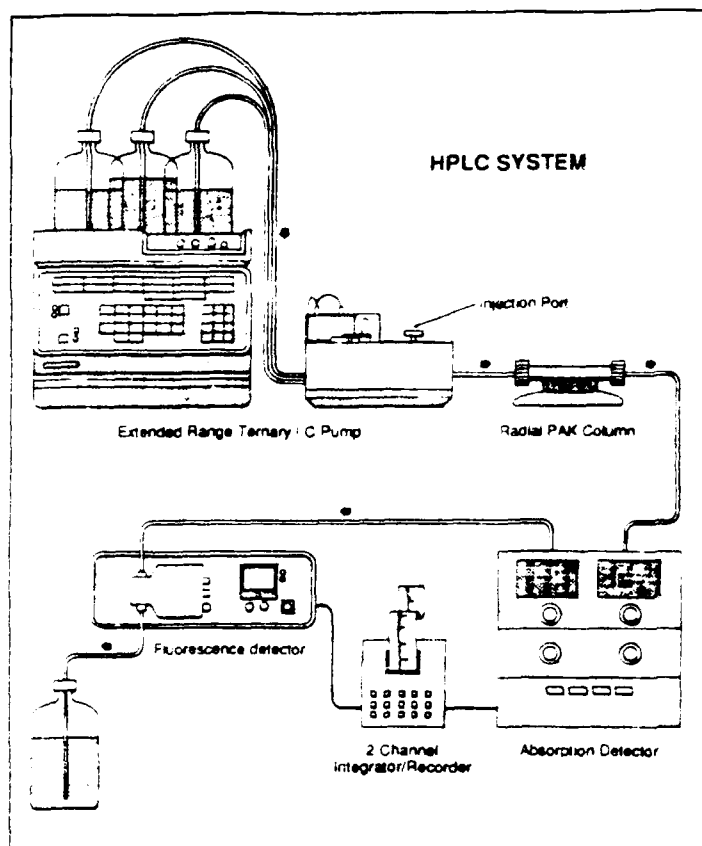


Figure 4. Simplified schematic of the high-performance liquid chromatography (HPLC) system.

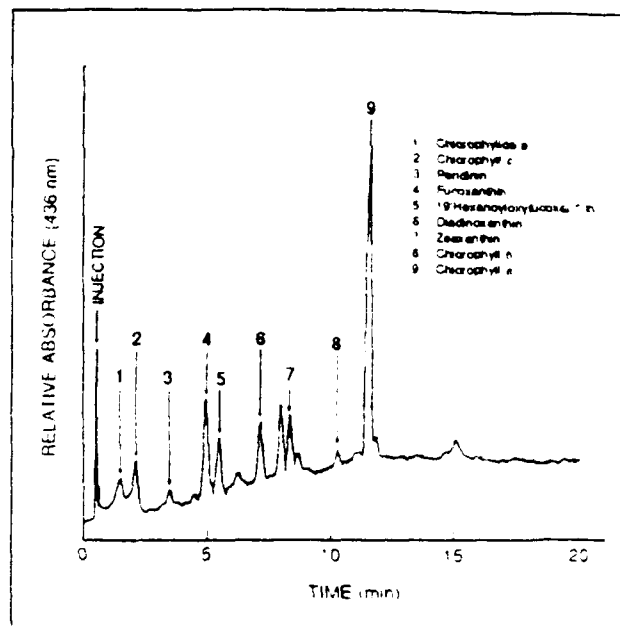


Figure 5. HPLC absorbance sample chromatogram.

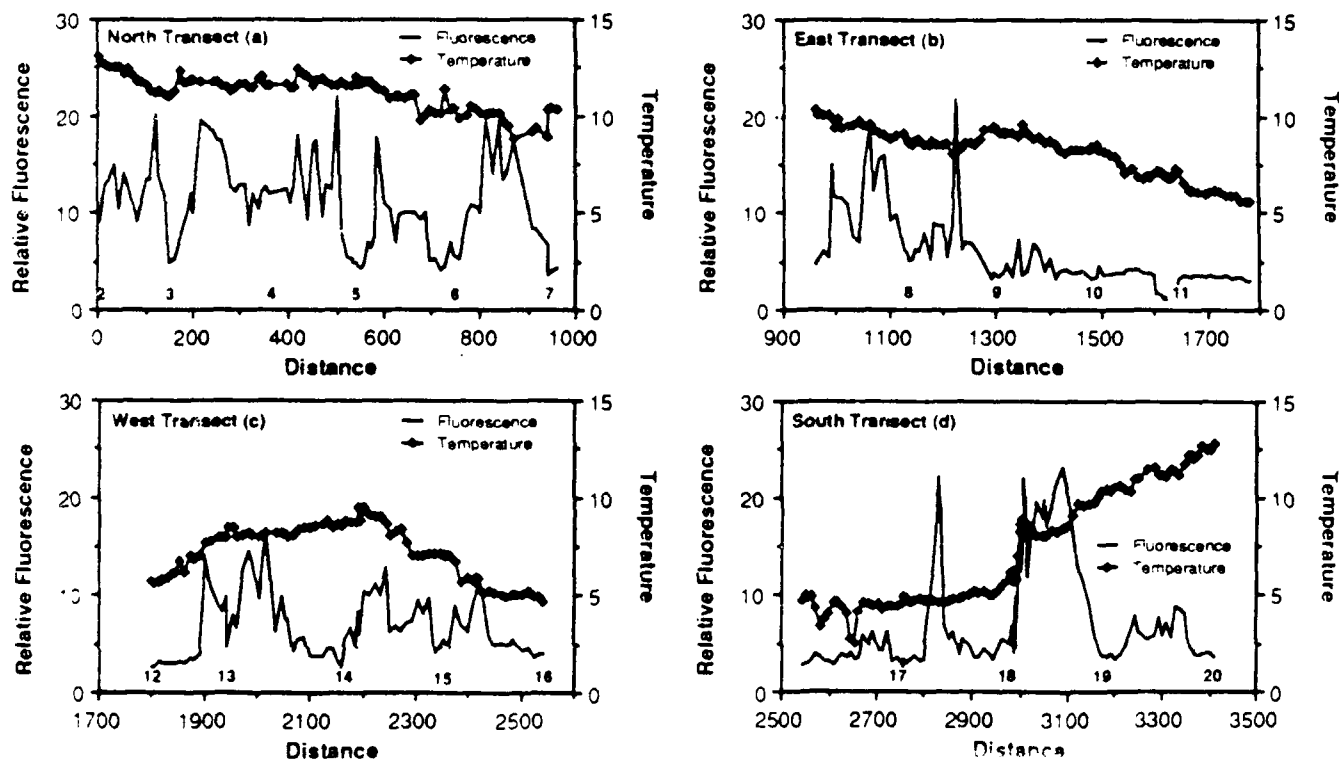


Figure 6. Sub-surface temperature and fluorescence along the four transects. The transect has been divided into four sections (North, East, West and South) with approximate station locations listed.

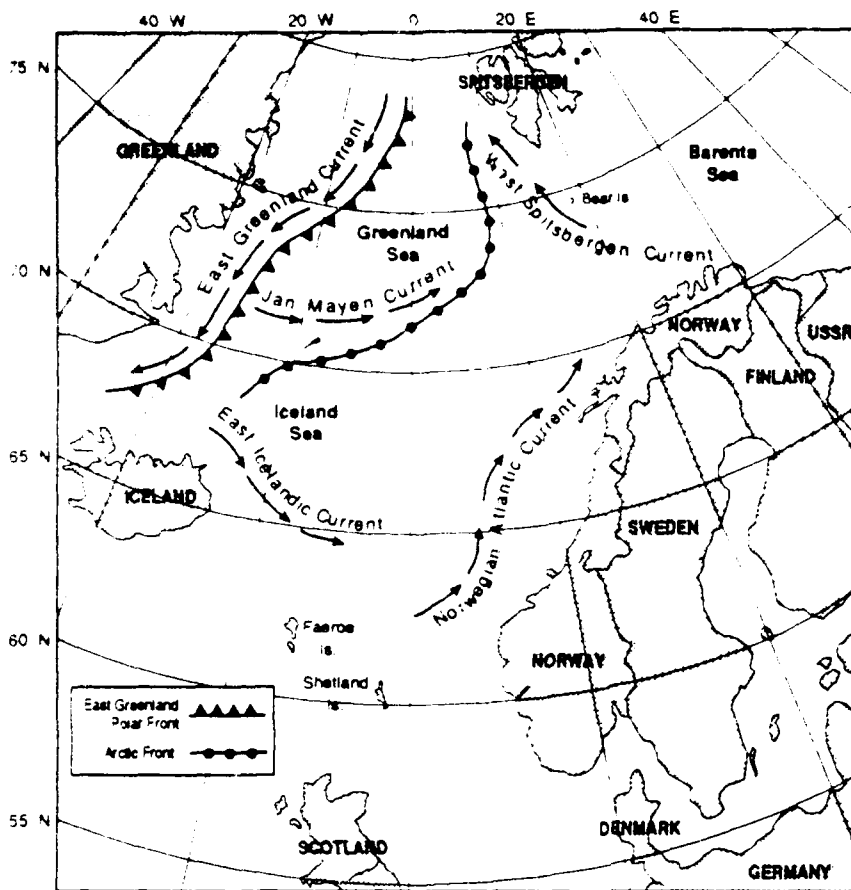


Figure 7. Currents and fronts in the Greenland-Norwegian Sea derived from a variety of sources (Swift, 1986).

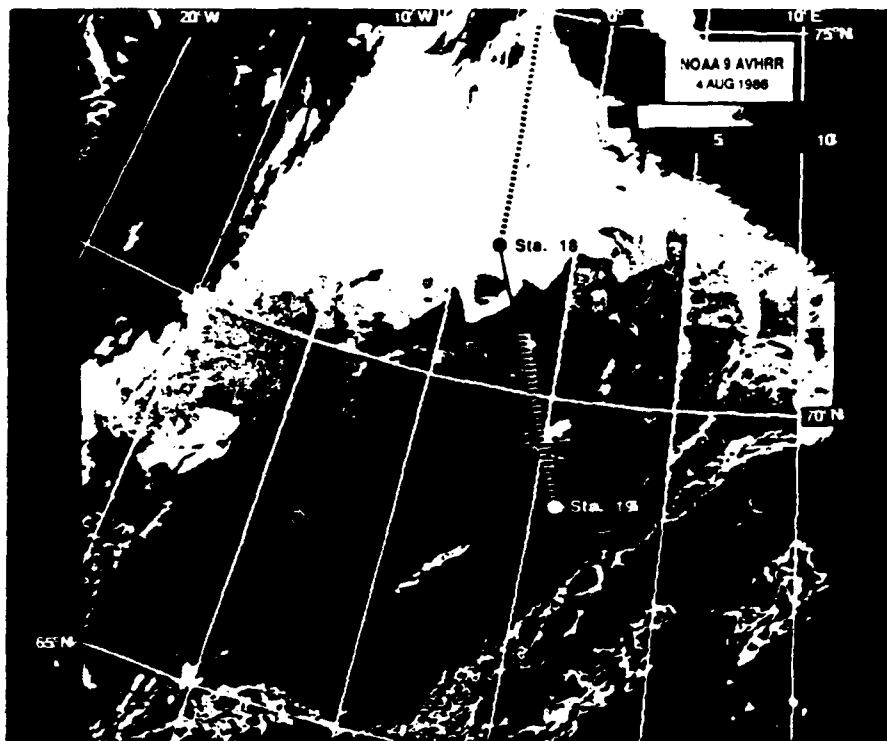


Figure 8. UOR transect of the Arctic Front (solid line) and continuous sub-surface track line (dotted plus solid lines) superimposed over an AVHRR sea surface temperature image for 4 August 1986 of the Greenland Sea.

Arctic Front which is dominated by Atlantic waters; and the Arctic domain, the transitional region between these fronts).

An AVHRR sea surface temperature image (4 August 1986) of the Greenland Sea is shown in Figure 8 and superimposed on it is the location of a 60 mile UOR transect (solid line) across the Arctic Front on 19 August, 15 days later. Sea surface temperature expressions of this front extend continuously from just south of Jan Mayen Island across the Greenland Sea to the southwestern edge of Spitsbergen (77°N 10°E). Numerous eddies, which have a general westward translation, can be observed along the front, as well as, vorticity structures further south several hundred miles. The much warmer waters of the Atlantic domain (darker area) can be observed near the bottom of the image. Using additional imagery from previous years, the Arctic Front has been found to be a permanent feature following bottom topography (Mohs and Knipovich Ridges).

UOR measurements confirm this inhomogeneity, as inferred from the satellite imagery, of the surface and sub-surface bio-optical fields over relatively short spatial scales in both Arctic and Atlantic domain waters. Such changes are shown in Figure 9 as vertical sections of temperature and chlorophyll concentrations for the 60 mile UOR transect. From the temperature profile, the Arctic Front was encountered halfway through the tow with a surface temperature change from less than 6°C to over 9°C within 10 miles. The steep thermal boundary coincided with a pigment gradient which had maximum chlorophyll concentrations above 1.8 mg m^{-3} in the upper 20 meters. This was in contrast to the sub-surface chlorophyll peak of 1.0 mg m^{-3} in the thermocline in the Arctic waters north of the front. The UOR was retrieved while chlorophyll concentrations were still elevated and therefore, the width of this surface pigment bloom could not be ascertained from the data. Using continuous *in vivo* fluorescence data from the shipboard sea chest, the width was found to be 150 miles with the magnitude of the fluorescence signal verified by discrete HPLC measured samples (Figure 10b).

With the exception of the vertical and horizontal structure of the chlorophyll

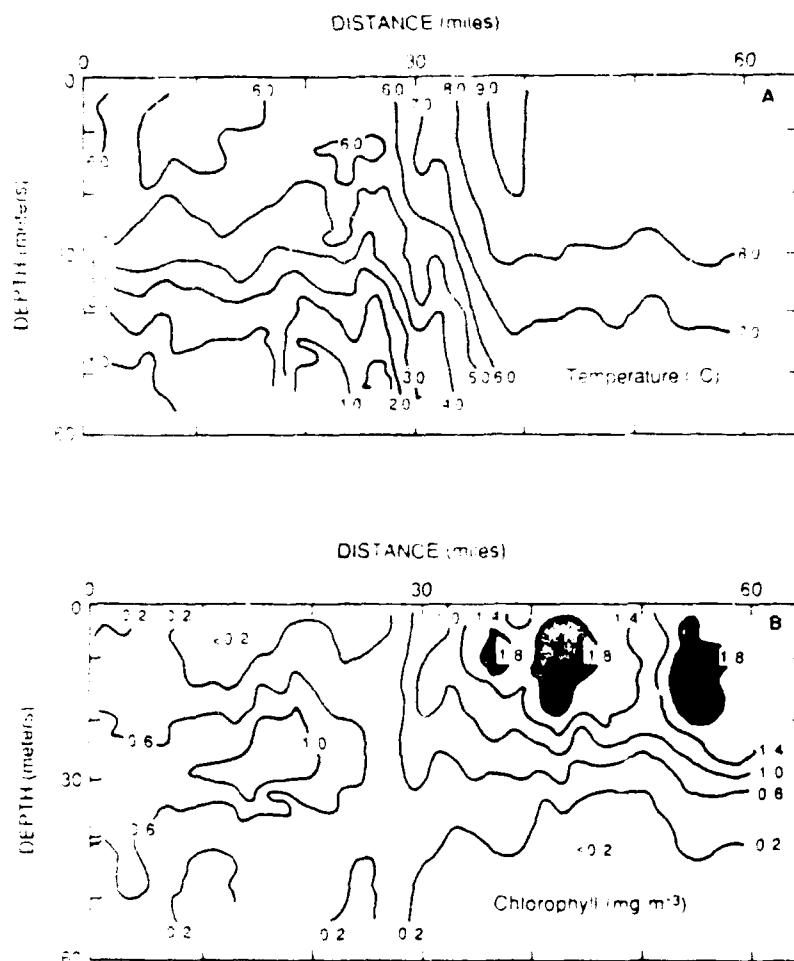


Figure 9. Vertical sections of temperature ($^{\circ}\text{C}$) and chlorophyll concentrations (mg m^{-3}) as determined by *in vivo* fluorescence during a transect across the Arctic Front (19 August 1986) of the Undulating Oceanographic Recorder (UOR).

field, the optical properties likewise spatially change. Since ocean color is determined by the backscattered irradiance which originates from depths above the 37% light level ($1/K$), the analysis of the UOR data can be restricted to the upper 20m or within the mixed layer depth. Figure 11 shows average values for temperature, chlorophyll, diffuse attenuation coefficient (K) and reflectance (R) across the Arctic Front; where the points were derived by averaging or regressing the data from 0 to 20m meters of each undulation. The frontal boundary is depicted by a sharp bio-optical gradient; such that, within in one UOR undulation (an horizontal distance of 0.8 miles) the average chlorophyll concentration doubled and $K(450)$ increased by 38%. A comparison of the average bio-optical prop-

ties on either side of the front is listed in Table 3. Both $K(450)$ and $K(550)$ increased across the front indicating a shallowing of the optical depths from 8.8 to 4.9m and from 10.6 to 8.2m, respectively. Reflectance at 450nm showed a 24.5% decrease due to the increase in absorption by the phytoplankton; whereas, $R(550)$ showed no discernible change.

Changes in the vertical structure of chlorophyll concentration across the front infer that different phytoplankton assemblages were exploiting the different physio-chemical environments of each water mass. These changes have been confirmed by both phytoplankton identification and enumeration and HPLC pigment analysis. A small number of phytoplankton samples were analyzed which showed the presence of *Thalassiosira*

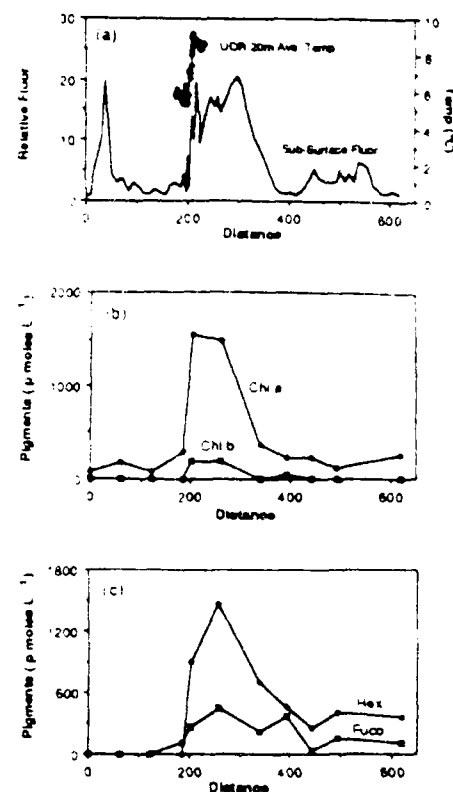


Figure 10. Pigment concentrations during a 620-mile transect across the Arctic Front

delicatissima cleve; ca. $75,000 \text{ l}^{-1}$) and occasionally unquantified numbers of *Phaeocystis pouchettii* in the Arctic waters; whereas, predominantly coccolithophorids (*Emiliania huxleyi*; ca. $100,000 \text{ l}^{-1}$ and *Coccolithus pelagicus*; ca. $11,000 \text{ l}^{-1}$, together with its crystalline phase; ca. $11,000 \text{ l}^{-1}$) were found south of the front, but still within the high pigment band. These coccolithophorid concentrations, although indicative of a bloom condition, are not excessively high, since Holligan *et al.* (1983) have reported values up to two orders of magnitude higher for waters around the English Channel.

Discrete sub-surface samples from the shipboard sea chest were analyzed by HPLC methods to quantify the suite of phytoplankton pigments present. Many of these pigment compounds can be used as bio-markers (Wright and Jeffrey, 1987) for various algal groups (e.g. chlorophyll *b* for green algae; fucoxanthin for diatoms; 19'-hexanoyloxyfucoxanthin for coccolithophorids, peridinin for dinoflagellates). A 620 mile transect of subsurface temperature, chlorophyll and pigment profiles

Table 3. Summary of bio-optical properties of the two different water masses as measured from the UOR.

	Arctic Domain	Atlantic Domain
Temperature ($^{\circ}\text{C}$)	5.68 ± 0.28	8.33 ± 0.17
Chlorophyll (mg m^{-3})	0.37 ± 0.12	1.52 ± 0.34
K(450) (m^{-1})	0.114 ± 0.008	0.205 ± 0.025
K(550) (m^{-1})	0.094 ± 0.009	0.122 ± 0.011
R(450)	0.049 ± 0.005	0.037 ± 0.006
R(550)	0.043 ± 0.007	0.044 ± 0.004

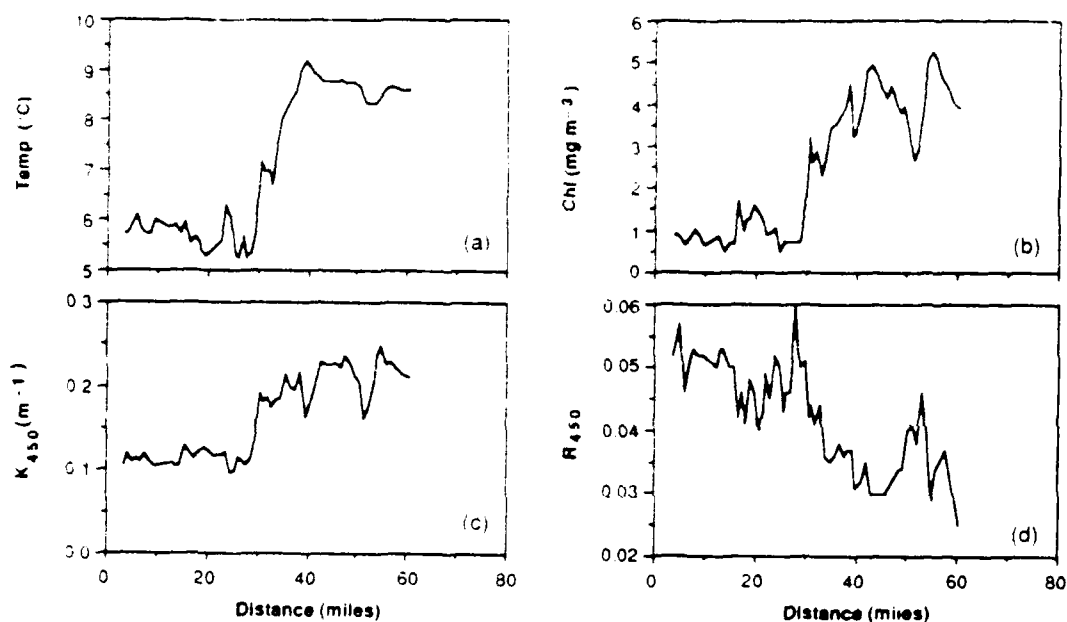


Figure 11. Twenty-meter averages for temperature ($^{\circ}\text{C}$), chlorophyll (mg m^{-3}), diffuse attenuation coefficient (m^{-1}) and reflectance across the Arctic Front during a UOR tow.

10a, b, and c which started around $75^{\circ} 20' \text{N}$ $3^{\circ} 45' \text{W}$ in Arctic domain waters and went through Station 18 and the Arctic Front and ended at Station 19 (Atlantic domain waters; see Figure 8, dashed and solid lines). Two samples were collected within the pigment band indicating over a five fold increase in chlorophyll *a* concentrations (Figure 10b). Fucoxanthin and hexanoyloxyfucoxanthin also increased with hexanoyloxyfucoxanthin, a coccolithophoride marker, increasing from below detection limits to up to 1500 picomoles L^{-1} (Figure 10b). South of the pigment band (500 miles and farther) hexanoyloxyfucoxanthin concentrations were still elevated relative to fucoxanthin, indicating the existence of a resident population of coccolithophorids in Atlantic domain waters.

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Appendix A. HPLC Derived Phytoplankton Pigment Concentrations from NOSC 86 Cruise in the Greenland and Barents Seas; Station Data

Sta. No.	Depth	Chl a	Chl b	Chl c	Chlde a	Peridinin	Fuco	Hex	Diadino	Carotene
2	0	898	548	139	94	118	161	533	178	78
2	10	872	411	161	102	118	0	417	246	65
2	20	1287	627	185	104	162	198	623	158	105
2	35	1168	551	171	105	140	142	546	246	83
2	40	1486	332	159	90	124	93	224	88	78
2	45	175	0	0	0	0	0	69	0	0
2	50	137	0	0	0	0	18	28	0	0
2	60	76	0	0	0	0	0	0	0	17
2	80	49	0	0	0	0	0	0	0	0
2	100	44	0	0	0	0	0	0	0	0
2	150	29	0	0	0	0	0	0	0	0
5	0	896	328	92	104	0	126	564	269	39
5	5	961	359	96	111	0	122	599	258	31
5	10	643	0	94	168	0	124	485	100	0
5	15	822	236	83	76	0	144	523	119	0
5	20	719	181	62	40	0	269	611	141	0
5	25	398	0	78	79	0	63	274	83	0
5	30	465	0	0	94	0	101	307	74	23
5	35	430	108	69	80	0	122	249	0	14
5	50	278	202	43	64	0	108	87	41	16
5	75	50	0	0	0	0	0	0	0	0
5	100	66	0	0	0	0	0	0	0	0
5	150	61	0	0	0	0	0	0	0	0
6	0	530	110	67	52	0	119	263	26	24
6	10	687	387	97	106	0	140	252	81	56
6	20	630	0	82	70	0	156	292	98	0
6	25	825	343	141	114	0	180	508	75	25
6	30	889	202	137	109	0	184	558	51	24
6	35	1020	230	168	177	24	266	578	51	36
6	40	942	179	146	137	0	304	411	24	37
6	45	692	0	75	91	36	250	317	25	0
6	50	600	193	60	67	69	177	257	29	23
6	75	101	0	0	0	0	43	0	0	0
6	100	65	0	0	0	0	0	0	0	0
6	150	87	0	0	0	0	0	0	0	0
8	0	412	0	84	57	0	165	144	125	0
8	10	648	0	130	60	0	227	160	121	14
8	15	655	0	82	63	0	239	159	105	0
8	20	639	0	116	82	0	252	165	83	19
8	25	684	0	99	68	0	258	188	25	20
8	30	567	0	83	57	0	223	149	48	34
8	35	667	0	147	74	0	184	191	70	0
8	40	539	0	99	89	0	293	176	31	0
8	50	624	0	107	103	0	425	0	26	26
8	75	151	0	0	0	0	42	54	0	17
8	100	113	0	0	0	0	85	0	0	41
9	0	382	0	0	0	0	130	129	0	42
9	10	433	145	71	0	0	242	143	0	0
9	15	348	115	81	31	0	128	83	26	25
9	20	664	287	148	86	0	305	239	0	44

Appendix A. HPLC Derived Phytoplankton Pigment Concentrations from NOSC 86 Cruise in the Greenland and Barents Seas; Station Data

Sta. No.	Depth	Chl a	Chl b	Chl c	Chl d	Peridinin	Fuco	Hex	Diadino	Carotene
9	25	608	305	137	76	0	269	197	93	39
9	30	370	195	75	37	0	130	131	0	23
9	35	542	283	85	0	0	264	150	0	0
9	40	234	0	47	0	0	122	0	0	0
9	50	92	0	19	0	0	0	0	0	0
9	75	38	0	0	0	0	0	0	0	0
9	100	68	0	0	0	0	0	0	0	0
10	0	326	0	27	0	0	50	46	51	0
10	10	458	0	0	0	0	0	122	159	0
10	20	383	0	0	0	79	0	0	0	0
10	25	584	0	78	0	0	152	163	172	40
10	30	409	138	63	0	0	108	0	0	0
10	35	982	586	137	0	0	339	264	215	78
10	40	640	357	104	0	72	196	197	164	0
10	45	619	466	69	0	62	164	166	190	48
10	75	69	0	0	0	0	0	0	0	8
10	100	81	0	0	0	0	0	0	0	0
11	0	262	0	20	0	0	46	69	0	40
11	10	309	0	0	0	0	62	64	88	29
11	20	405	0	41	0	0	120	155	161	57
11	25	526	308	107	65	0	173	184	136	35
11	30	582	100	132	51	0	304	252	73	110
11	35	1262	323	261	123	53	577	306	110	74
11	40	950	278	205	101	236	245	200	152	54
11	45	606	225	123	68	146	171	143	99	0
11	50	518	250	67	72	0	199	148	104	41
11	75	70	0	0	0	0	49	0	0	0
11	150	47	0	0	0	0	0	0	0	0
12	0	360	451	0	0	0	0	136	0	68
12	10	434	534	0	0	0	67	0	0	52
12	20	503	535	0	0	0	50	101	0	87
12	25	453	490	29	0	0	0	134	0	70
12	30	206	160	0	0	0	0	0	0	26
12	35	1081	1216	72	0	0	142	337	176	93
12	40	1654	1501	128	0	0	221	452	255	114
12	45	2093	1909	122	0	0	284	496	288	135
12	50	721	610	46	0	0	76	72	0	48
12	75	100	0	0	0	0	0	0	0	0
12	100	56	0	0	0	0	0	19	11	0
12	150	44	0	0	0	0	0	0	0	0
13	0	387	0	86	68	0	223	90	136	0
13	10	660	0	153	105	0	487	168	165	0
13	15	640	0	295	128	0	925	144	0	0
13	20	776	0	272	212	0	638	275	205	0
13	25	737	0	244	280	0	516	393	203	0
13	30	628	0	189	180	0	481	261	146	0
13	35	633	0	177	193	0	522	184	62	0
13	40	302	0	50	0	0	173	119	39	0
13	45	504	0	122	101	0	266	168	97	44
13	75	249	0	32	0	0	130	60	63	22

Appendix A. HPLC Derived Phytoplankton Pigment Concentrations from NOSC 86 Cruise in the Greenland and Barents Seas; Station Data

Sta. No.	Depth	Chl a	Chl b	Chl c	Chlide a	Peridinin	Fuco	Hex	Diadino	Carotene
13	100	76	0	0	0	0	0	0	0	0
14	0	342	0	0	0	0	0	0	0	0
14	10	802	0	0	0	0	0	192	0	0
14	15	1006	112	0	0	0	354	452	0	0
14	20	379	74	190	0	0	307	414	0	0
14	25	718	345	84	88	0	351	452	0	0
14	30	482	162	82	65	0	96	317	0	28
14	35	695	0	58	39	0	372	357	0	177
14	40	544	0	46	39	0	284	314	0	0
14	45	312	0	20	21	0	193	279	0	17
14	75	117	0	0	0	0	0	0	0	0
15	0	603	0	75	0	0	184	509	0	0
15	15	1167	0	116	87	0	450	1158	0	0
15	20	1285	0	113	50	0	615	1315	0	0
15	25	528	0	109	69	0	258	770	0	0
15	30	855	0	195	120	87	194	1452	0	0
15	35	1030	0	170	124	124	738	1116	0	0
15	40	709	0	103	62	0	498	546	0	0
15	45	539	0	70	50	0	514	502	0	0
15	75	41	0	0	0	0	0	0	0	0
16	0	187	0	0	0	0	22	58	0	0
16	10	482	0	49	0	0	160	228	0	0
16	20	414	0	97	27	12	142	349	396	36
16	25	741	29	186	97	74	302	1022	237	53
16	30	838	128	213	114	105	352	1078	213	31
16	35	602	0	83	64	0	0	0	0	0
16	40	929	0	99	51	0	0	0	0	57
16	45	425	0	23	0	0	0	0	0	0
16	50	265	0	0	0	0	21	0	0	0
16	75	91	0	0	0	0	0	0	0	0
17	0	114	0	10	0	0	54	0	0	28
17	15	144	0	0	0	95	0	196	0	0
17	25	227	0	20	10	0	0	340	0	0
17	35	258	0	10	0	0	46	291	0	0
17	40	528	0	59	88	0	60	369	0	0
17	45	639	0	133	73	0	244	521	0	0
17	50	416	0	62	39	0	176	385	0	0
17	55	631	188	54	39	0	407	989	0	0
17	60	457	189	107	83	0	339	1054	0	0
17	75	308	55	31	35	0	337	399	0	0
17	100	137	147	0	0	0	172	504	0	0
17	150	52	0	0	0	0	0	0	0	0
18	0	285	0	31	0	93	120	0	0	0
18	15	665	0	63	41	167	283	296	0	0
18	25	364	0	77	62	0	326	365	0	0
18	35	779	0	158	105	0	245	98	0	0
18	40	952	0	172	149	0	504	352	144	0
18	45	804	0	113	120	0	42	592	759	0
18	50	763	0	72	130	47	576	787	460	80

Appendix A. HPLC Derived Phytoplankton Pigment Concentrations from NOSC 86 Cruise in the Greenland and Barents Seas; Station Data

Sta. No.	Depth	Chl a	Chl b	Chl c	Chlide a	Peridinin	Fuco	Hex	Diadino	Carotene
18	55	543	0	65	70	48	310	405	270	0
18	60	471	0	69	51	0	265	331	96	11
18	75	195	0	0	17	0	161	478	0	0
18	100	114	0	0	0	0	0	397	0	0
18	150	38	0	0	0	0	0	0	0	0
19	0	224	54	0	0	0	375	460	0	0
19	10	215	0	0	0	0	184	520	0	0
19	20	224	0	0	0	0	178	396	0	0
19	25	228	0	18	0	0	176	405	0	0
19	29	220	0	0	0	0	0	707	0	0
19	35	251	0	0	0	0	269	535	0	0
19	40	483	323	52	58	0	351	642	0	0
19	45	346	0	78	0	0	228	434	0	0
19	50	534	251	28	18	50	0	0	0	64
19	75	89	0	0	0	0	0	0	0	0
19	100	99	0	0	0	0	0	0	0	0
19	150	29	0	0	0	0	0	0	0	0
20	0	310	0	53	0	0	39	35	0	22
20	10	491	0	19	15	0	222	894	0	78
20	20	372	0	0	0	0	422	334	0	0
20	25	255	0	22	11	0	47	463	252	0
20	30	607	0	26	23	0	222	602	0	0
20	35	512	76	59	59	0	128	482	50	28
20	40	682	263	18	27	77	120	801	265	41
20	45	574	200	53	52	0	288	1056	0	76
20	50	394	265	35	32	0	34	148	14	0
20	75	37	0	0	0	0	0	0	0	0

Appendix B. HPLC Derived Phytoplankton Pigment Concentrations from NOSC 86 Cruise in the Greenland and Barents Seas; Surface Data

Date	Time (GMT)	Chl a	Chl b	Chl c	Chlide a	Peridinin	Fuco	Hex	Diadino	Carotene
14 Aug	1847	444	0	240	134	0	471	281	0	67
15 Aug	0000	586	0	118	74	0	451	459	0	48
15 Aug	0600	190	0	35	17	0	139	291	0	32
15 Aug	1942	310	0	53	27	0	191	401	0	68
16 Aug	1610	631	0	146	0	0	900	0	592	0
16 Aug	2023	746	139	86	0	0	687	676	920	0
16 Aug	2300	377	0	0	0	0	608	590	0	136
17 Aug	0106	252	0	0	0	0	61	300	0	0
17 Aug	0320	372	0	27	0	0	932	0	0	0
17 Aug	0503	121	0	0	0	0	0	0	0	0
17 Aug	0615	184	0	0	0	0	0	0	0	0
17 Aug	1509	191	0	70	16	25	104	128	0	0
17 Aug	1600	354	0	88	0	24	349	0	0	29
17 Aug	1700	356	0	106	48	0	265	235	0	74
17 Aug	1800	163	0	16	0	0	89	64	0	21
17 Aug	1900	133	0	15	15	0	135	163	0	38
17 Aug	2000	84	0	0	0	0	62	100	0	0
18 Aug	0000	203	0	14	0	0	221	222	0	79
18 Aug	1800	82	0	0	0	0	0	0	0	0
19 Aug	0000	171	0	0	0	97	0	0	145	0
19 Aug	0600	71	0	0	0	0	0	0	0	0
19 Aug	1700	1543	193	179	181	0	263	904	570	40
19 Aug	2230	1478	184	212	156	81	448	1462	949	211
20 Aug	0600	363	0	146	0	0	222	701	230	15
20 Aug	1809	228	0	26	31	0	34	256	0	45
20 Aug	2305	111	0	0	0	0	153	407	0	0
21 Aug	1435	249	0	12	9	0	108	360	0	35
21 Aug	1800	210	0	22	0	0	103	215	0	32

Appendix C. HPLC Derived Phytoplankton Pigment Concentrations from NOSC 87 Cruise in the Greenland Sea;
Station Data

Sta. No.	Depth	Chl a	Chl b	Chl c	Chl d + e	Peridinin	Fuco	Hex	Diadino	Carotene
3	0	267	179	60	54	0	0	0	0	0
3	10	290	106	73	57	0	100	207	94	0
3	30	357	179	94	77	0	123	232	92	23
3	25	276	161	73	70	0	114	213	70	23
3	35	367	188	72	84	0	108	227	0	26
3	50	235	71	53	78	0	30	108	20	0
3	75	50	0	15	21	0	0	32	0	0
4	0	747	181	216	258	0	168	649	276	33
4	10	862	191	230	257	0	179	715	293	38
4	30	756	164	222	178	27	342	444	123	45
4	25	511	0	192	167	20	335	281	94	27
4	35	577	124	188	161	19	370	294	79	19
4	50	233	0	49	76	0	46	103	15	9
4	75	97	0	29	52	0	0	95	0	7
5	0	963	402	201	179	0	224	476	218	32
5	25	894	285	226	233	0	273	520	140	47
5	35	484	198	114	164	0	220	254	70	29
5	40	423	50	104	153	0	180	191	22	9
5	50	242	110	55	92	0	112	117	53	21
5	75	78	0	12	25	0	0	0	0	0
6	0	997	226	259	232	0	283	517	273	33
6	10	1052	156	243	198	0	299	532	272	51
6	20	1172	293	308	256	0	358	602	244	50
6	30	730	222	213	219	0	298	391	102	25
6	40	424	104	101	132	0	212	193	59	25
6	50	153	72	38	56	0	96	79	38	0
6	75	56	0	0	0	0	19	0	0	0
7	0	632	356	219	193	0	339	242	207	54
7	10	588	196	226	241	0	306	192	76	43
7	25	743	302	274	246	0	402	233	99	47
7	30	710	212	404	517	0	573	286	136	49
7	35	513	177	200	250	0	394	188	56	42
7	50	260	0	62	65	0	118	11	0	14
7	75	55	0	0	0	0	21	0	14	0
8	0	749	186	209	163	29	261	320	114	39
8	10	661	144	178	162	0	288	311	123	118
8	20	817	101	274	195	0	299	363	119	43
8	30	804	158	326	324	0	346	418	125	23
8	35	885	95	254	281	0	495	392	100	20
8	50	596	128	157	188	0	383	244	80	31
8	75	91	0	24	0	0	28	0	0	12
9	0	639	264	253	258	0	281	333	196	92
9	10	725	217	234	174	0	245	286	190	34
9	20	728	214	246	148	0	287	355	183	35
9	30	749	84	271	265	0	367	379	102	37
9	40	624	118	186	254	0	379	309	81	24
9	50	865	103	236	362	0	464	411	103	38
9	75	147	74	45	56	0	110	80	49	30

Appendix C. HPLC Derived Phytoplankton Pigment Concentrations from NOSC 87 Cruise in the Greenland Sea;
Station Data

Sta. No.	Depth	Chl a	Chl b	Chl c	Chl d	Peridinin	Fuco	Hex	Diadino	Carotene
10	0	1012	272	316	230	0	456	365	256	46
10	10	853	271	302	266	0	395	337	186	30
10	20	1216	305	305	177	0	458	399	208	39
10	30	1206	286	379	288	0	532	463	146	11
10	40	1186	308	281	313	20	474	571	91	28
10	50	1394	196	255	448	86	441	792	87	40
10	75	69	0	16	0	0	0	0	0	0
11	0	541	107	149	52	0	242	189	63	37
11	10	448	150	125	52	0	208	165	58	28
11	20	414	140	132	67	36	192	155	112	14
11	30	222	98	72	36	0	146	81	62	0
11	40	377	98	116	60	57	162	39	14	14
11	50	543	141	188	136	134	257	133	89	0
11	75	255	0	76	47	41	115	65	13	21
12	0	744	165	229	187	46	260	372	134	23
12	10	862	202	259	183	0	287	427	152	34
12	20	864	87	272	193	0	238	405	133	27
12	30	767	111	217	137	0	244	392	129	22
12	40	1015	115	224	319	55	406	543	123	41
12	50	240	0	58	73	22	163	126	44	0
12	75	58	0	0	11	0	0	0	0	0
13	0	956	202	258	209	68	374	365	160	27
13	10	921	217	288	205	55	336	393	174	37
13	20	923	214	288	184	51	369	397	169	27
13	30	682	206	222	174	53	299	337	123	25
13	40	309	98	85	81	39	207	109	48	24
13	50	274	158	48	52	42	169	104	0	23
13	75	45	0	12	0	42	0	0	0	0
14	0	1234	315	280	186	44	344	562	224	38
14	10	1402	248	386	302	31	415	673	61	30
14	20	1779	300	480	330	60	501	808	81	41
14	30	1636	68	439	407	66	431	738	52	24
14	40	1672	44	452	705	64	498	868	79	8
14	50	619	132	159	182	40	289	160	68	18
14	75	200	74	46	42	102	125	68	48	9
15	0	363	0	114	76	0	113	186	122	0
15	10	304	0	96	76	0	120	180	111	0
15	20	1176	104	518	338	42	480	594	99	20
15	30	911	104	320	381	0	475	588	64	13
15	40	566	142	209	239	26	444	232	43	0
15	50	190	74	56	62	0	153	64	0	0
15	75	554	76	193	170	0	272	285	100	0
16	0	510	175	122	85	0	208	130	0	40
16	10	988	179	227	134	0	379	150	176	53
16	17	1801	200	630	433	0	858	315	173	43
16	30	1060	149	241	198	51	519	188	68	31
16	40	1147	152	253	145	103	816	204	158	30
16	55	958	164	232	134	0	848	194	64	34

Appendix C. HPLC Derived Phytoplankton Pigment Concentrations from NOSC 87 Cruise in the Greenland Sea;
Station Data

Sta. No.	Depth	Chl a	Chl b	Chl c	Chlide a	Peridrin	Fuco	Hex	Diadino	Carotene
16	75	157	82	37	43	0	135	42	34	0
17	0	423	0	169	154	0	163	310	135	0
17	10	568	190	185	152	0	180	373	94	0
17	20	508	88	180	142	0	183	347	136	0
17	30	580	0	211	176	0	196	392	64	28
17	40	532	0	180	205	0	204	316	41	0
17	50	282	0	93	117	32	162	79	10	35
17	75	46	0	0	0	0	0	0	0	0
18	0	466	158	142	89	35	161	250	146	30
18	10	461	0	154	90	26	148	276	131	20
18	20	406	85	156	111	17	128	270	77	6
18	30	437	128	166	143	23	145	319	82	19
18	40	568	139	185	222	34	193	418	77	12
18	50	746	183	219	299	90	291	356	88	21
18	75	84	0	25	16	0	29	0	0	0
19	0	882	232	271	233	0	288	572	221	23
19	10	1027	231	318	264	0	273	692	260	34
19	20	1096	121	309	242	0	355	783	81	0
19	30	973	258	271	327	26	390	466	38	0
19	40	936	191	246	366	48	400	489	80	30
19	50	537	69	80	96	15	228	188	39	11
19	75	49	0	0	0	0	28	0	0	0
20	0	670	115	274	230	0	360	356	223	18
20	10	615	108	222	184	0	308	338	216	15
20	20	1238	140	393	307	0	564	742	116	42
20	25	622	173	236	202	0	230	374	96	42
20	30	768	160	256	297	48	277	408	110	30
20	40	924	128	243	327	124	448	415	107	22
20	60	130	95	18	10	0	93	60	68	29
21	0	302	0	91	78	0	136	0	50	23
21	10	384	0	114	87	0	189	0	41	16
21	20	981	257	394	398	40	674	0	99	17
21	25	1605	205	721	825	112	1083	278	168	59
21	30	2605	148	831	1184	235	1255	1213	149	56
21	40	1149	197	275	385	120	494	321	91	38
21	60	356	0	85	191	14	162	176	19	0
22	0	483	129	150	118	0	277	108	124	34
22	10	427	188	109	102	0	253	132	127	0
22	15	463	173	131	100	0	309	0	132	26
22	20	560	204	161	128	0	344	144	128	29
22	30	573	95	243	257	0	427	113	0	0
22	40	762	102	281	372	56	530	0	27	31
22	60	537	36	173	298	16	301	63	24	20
23	0	395	0	125	112	0	232	127	100	17
23	10	363	0	115	86	0	186	0	78	0
23	20	789	140	277	260	0	646	193	143	58
23	25	668	184	306	285	0	557	150	96	25

Appendix C. HPLC Derived Phytoplankton Pigment Concentrations from NOSC 87 Cruise in the Greenland Sea:
Station Data

Sta. No.	Depth	Chl a	Chl b	Chl c	Chl d	Peridinin	Fuco	Hex	Diatino	Carotene
23	30	848	194	336	329	0	700	185	105	26
23	40	705	168	261	311	35	512	0	76	12
23	60	428	113	123	206	0	218	80	18	28
24	0	292	143	100	86	0	81	172	74	22
24	10	290	117	91	76	0	78	172	68	20
24	20	336	146	101	80	0	80	191	66	24
24	25	308	94	97	79	0	66	187	58	17
24	30	290	134	93	82	0	62	177	52	21
24	40	406	104	132	154	0	99	248	36	23
24	60	331	42	89	147	0	79	198	0	18
25	10	206	109	76	62	0	77	118	69	0
25	20	137	0	81	72	0	69	100	48	0
25	30	302	115	95	72	0	86	155	79	15
25	40	389	178	118	104	0	122	198	81	25
25	50	297	182	88	76	0	114	147	96	29
25	60	82	0	36	37	0	54	36	0	0
26	0	250	0	110	81	0	86	152	85	18
26	10	201	74	101	87	0	0	130	63	3
26	20	216	0	132	101	0	108	169	63	0
26	30	204	0	109	97	0	86	155	55	0
26	40	315	141	84	88	0	67	158	0	33
26	50	248	146	48	59	0	0	114	0	33
26	75	35	0	0	0	0	0	0	0	0
27	0	149	0	67	54	0	80	109	84	16
27	10	149	0	76	64	0	66	97	51	32
27	20	253	82	104	86	0	109	175	102	33
27	30	382	214	124	123	0	164	203	103	73
27	40	254	92	105	116	0	45	105	22	16
27	50	209	175	73	88	0	0	138	0	0
27	75	116	90	35	44	0	0	57	0	10

Appendix D. HPLC Derived Phytoplankton Pigment Concentrations from NOSC 87 Cruise in the Greenland Sea:
Surface Data

Date	Time (GMT)	Chl a	Chl b	Chl c	Chlide a	Peridinin	Fuco	Hex	Diadino	Carotene
2Aug	1900	710	167	197	200	0	155	518	233	34
2Aug	1935	1147	131	347	390	0	176	979	343	46
2Aug	1957	1303	179	352	428	0	162	1126	228	47
3Aug	1800	521	207	296	237	0	432	312	213	0
4Aug	0825	507	96	171	126	0	230	149	110	24
4Aug	1934	798	260	703	944	0	720	0	375	25
5Aug	0100	403	118	133	91	0	182	193	75	0
5Aug	2045	1011	289	428	422	0	533	424	277	37
5Aug	2223	691	132	213	164	0	298	264	167	25
6Aug	0026	0	0	0	0	0	0	0	0	0
6Aug	0100	493	219	130	93	0	154	273	132	0
6Aug	0230	502	183	137	101	0	194	258	139	20
6Aug	0430	404	135	122	91	0	182	225	62	14
6Aug	0515	353	56	118	60	0	162	20	64	0
6Aug	0606	335	95	88	43	0	168	97	66	22
6Aug	0646	244	0	76	31	0	125	80	28	0
6Aug	1830	217	72	65	46	0	81	88	23	15
7Aug	0120	381	79	134	84	15	154	144	87	21
7Aug	0121	626	210	194	180	48	257	347	104	25
7Aug	0122	910	301	274	216	29	358	401	132	34
7Aug	0123	556	74	179	119	60	252	265	118	32
7Aug	0124	850	80	269	179	77	370	384	168	36
7Aug	1312	1285	336	323	205	69	456	567	251	38
7Aug	1348	2768	1508	1125	569	0	1390	1123	984	222
9Aug	2203	926	199	334	234	37	384	495	219	32
10Aug	0502	518	53	302	188	0	251	270	126	30
10Aug	0615	617	187	296	119	0	370	226	186	50
10Aug	0339	1004	210	534	215	0	784	375	293	36
10Aug	0329	952	194	439	128	0	642	349	274	71
10Aug	0300	322	130	254	246	0	293	214	130	42

Appendix A. HPLC-Derived Phytoplankton Pigment Concentrations from NOSC 86 Cruise in the Greenland and Barents Seas; Station Data

Sta. No.	Depth	Chl a	Chl b	Chl c	Chl d	Peridinin	Fuco	Hex	Diadino	Carotene
2	0	898	548	139	94	118	161	533	178	78
2	10	872	411	161	102	118	0	417	246	65
2	20	1287	627	185	104	162	198	623	158	105
2	35	1168	551	171	105	140	142	546	246	83
2	40	1486	332	159	90	124	93	334	88	78
2	45	175	0	0	0	0	0	69	0	0
2	50	137	0	0	0	0	18	28	0	0
2	60	76	0	0	0	0	0	0	0	17
2	80	49	0	0	0	0	0	0	0	0
2	100	44	0	0	0	0	0	0	0	0
2	150	29	0	0	0	0	0	0	0	0
5	0	896	328	92	104	0	126	564	269	39
5	5	961	359	96	111	0	122	599	258	31
5	10	643	0	94	168	0	124	485	100	0
5	15	822	236	83	76	0	144	523	119	0
5	20	719	181	62	40	0	269	611	141	0
5	25	398	0	78	79	0	63	274	83	0
5	30	465	0	0	94	0	101	307	74	23
5	35	430	108	69	80	0	122	249	0	14
5	50	278	202	43	64	0	108	87	41	16
5	75	50	0	0	0	0	0	0	0	0
5	100	66	0	0	0	0	0	0	0	0
5	150	61	0	0	0	0	0	0	0	0
6	0	530	110	67	52	0	119	263	26	24
6	10	687	387	97	106	0	140	252	81	56
6	20	630	0	82	70	0	156	292	98	0
6	25	825	343	141	114	0	180	508	75	25
6	30	889	202	137	109	0	184	558	51	24
6	35	1020	230	168	177	24	266	578	51	36
6	40	942	179	146	137	0	304	411	24	37
6	45	692	0	75	91	36	250	317	25	0
6	50	600	193	60	67	69	177	257	29	23
6	75	101	0	0	0	0	43	0	0	0
6	100	65	0	0	0	0	0	0	0	0
6	150	87	0	0	0	0	0	0	0	0
8	0	412	0	84	57	0	165	144	125	0
8	10	648	0	130	60	0	227	160	121	14
8	15	655	0	82	63	0	239	159	105	0
8	20	639	0	116	82	0	252	165	83	19
8	25	684	0	99	68	0	258	188	25	20
8	30	567	0	83	57	0	223	149	48	34
8	35	667	0	147	74	0	184	191	70	0
8	40	539	0	99	89	0	293	176	31	0
8	50	624	0	107	103	0	425	0	26	26
8	75	151	0	0	0	0	42	54	0	17
8	100	113	0	0	0	0	85	0	0	41
9	0	382	0	0	0	0	130	129	0	42
9	10	433	145	71	0	0	242	143	0	0
9	15	348	116	81	31	0	128	83	26	25
9	20	664	287	148	86	0	305	239	0	44

Appendix A. HPLC-Derived Phytoplankton Pigment Concentrations from NOSC 86 Cruise in the Greenland and Barents Seas; Station Data

Sta. No.	Depth	Chl a	Chl b	Chl c	Chlde a	Peridinin	Fuco	Hex	Diadino	Carotene
9	25	608	305	137	76	0	269	197	93	39
9	30	370	195	75	37	0	130	131	0	23
9	35	542	283	85	0	0	264	150	0	0
9	40	234	0	47	0	0	122	0	0	0
9	50	92	0	19	0	0	0	0	0	0
9	75	38	0	0	0	0	0	0	0	0
9	100	68	0	0	0	0	0	0	0	0
10	0	326	0	27	0	0	50	46	51	0
10	10	458	0	0	0	0	0	122	159	0
10	20	383	0	0	0	79	0	0	0	0
10	25	584	0	78	0	0	152	163	172	40
10	30	409	138	63	0	0	108	0	0	0
10	35	982	586	137	0	0	339	264	215	78
10	40	640	357	104	0	72	196	197	164	0
10	45	619	466	69	0	62	164	166	190	48
10	75	69	0	0	0	0	0	0	0	8
10	100	81	0	0	0	0	0	0	0	0
11	0	262	0	20	0	0	46	69	0	40
11	10	309	0	0	0	0	62	64	88	29
11	20	405	0	41	0	0	120	155	161	57
11	25	526	308	107	65	0	173	184	136	35
11	30	582	100	132	51	0	304	252	73	110
11	35	1262	323	261	123	53	523	306	110	74
11	40	950	278	205	101	236	245	200	152	54
11	45	606	225	123	68	146	171	143	99	0
11	50	518	250	67	72	0	199	148	104	41
11	75	70	0	0	0	0	49	0	0	0
11	150	47	0	0	0	0	0	0	0	0
12	0	360	451	0	0	0	0	136	0	68
12	10	434	534	0	0	0	67	0	0	52
12	20	503	535	0	0	0	50	101	0	87
12	25	453	490	29	0	0	0	134	0	70
12	30	206	160	0	0	0	0	0	0	26
12	35	1081	1216	72	0	0	142	337	176	93
12	40	1654	1501	128	0	0	221	452	255	114
12	45	2093	1909	122	0	0	284	496	288	135
12	50	721	610	46	0	0	76	72	0	48
12	75	100	0	0	0	0	0	0	0	0
12	100	56	0	0	0	0	0	19	11	0
12	150	44	0	0	0	0	0	0	0	0
13	0	387	0	86	68	0	223	90	136	0
13	10	660	0	153	105	0	487	168	165	0
13	15	640	0	295	128	0	925	144	0	0
13	20	776	0	272	212	0	638	275	205	0
13	25	737	0	244	280	0	516	393	203	0
13	30	628	0	189	180	0	481	261	146	0
13	35	633	0	177	193	0	522	184	62	0
13	40	302	0	50	0	0	173	119	39	0
13	45	504	0	122	101	0	266	168	97	44
13	75	249	0	32	0	0	130	60	63	22

Appendix A. HPLC-Derived Phytoplankton Pigment Concentrations from NOSC 86 Cruise in the Greenland and Barents Seas; Station Data

Sta. No.	Depth	Chl a	Chl b	Chl c	Chlde a	Peridinin	Fuco	Hex	Diadino	Carotene
13	100	76	0	0	0	0	0	0	0	0
14	0	342	0	0	0	0	0	0	0	0
14	10	802	0	0	0	0	0	192	0	0
14	15	1006	112	0	0	0	354	452	0	0
14	20	379	74	190	0	0	307	414	0	0
14	25	718	345	84	88	0	351	452	0	0
14	30	482	162	82	65	0	96	317	0	28
14	35	695	0	58	39	0	372	357	0	177
14	40	544	0	46	39	0	284	314	0	0
14	45	312	0	20	21	0	193	279	0	17
14	75	117	0	0	0	0	0	0	0	0
15	0	603	0	75	0	0	184	509	0	0
15	15	1167	0	116	87	0	450	1158	0	0
15	20	1285	0	113	50	0	615	1315	0	0
15	25	528	0	109	69	0	258	770	0	0
15	30	855	0	195	120	87	194	1452	0	0
15	35	1030	0	170	124	124	738	1116	0	0
15	40	709	0	103	62	0	498	646	0	0
15	45	539	0	70	50	0	514	502	0	0
15	75	41	0	0	0	0	0	0	0	0
16	0	187	0	0	0	0	22	58	0	0
16	10	482	0	49	0	0	160	228	0	0
16	20	414	0	97	27	12	142	349	396	36
16	25	741	29	186	97	74	302	1022	237	53
16	30	838	128	213	114	105	352	1078	213	31
16	35	602	0	83	64	0	0	0	0	0
16	40	929	0	99	51	0	0	0	0	57
16	45	425	0	23	0	0	0	0	0	0
16	50	265	0	0	0	0	21	0	0	0
16	75	91	0	0	0	0	0	0	0	0
17	0	114	0	10	0	0	54	0	0	28
17	15	144	0	0	0	95	0	196	0	0
17	25	227	0	20	10	0	0	340	0	0
17	35	258	0	10	0	0	46	291	0	0
17	40	528	0	59	88	0	60	369	0	0
17	45	639	0	133	73	0	244	521	0	0
17	50	416	0	62	39	0	176	385	0	0
17	55	631	188	54	39	0	407	989	0	0
17	60	457	189	107	83	0	339	1054	0	0
17	75	308	55	31	35	0	337	399	0	0
17	100	137	147	0	0	0	172	504	0	0
17	150	52	0	0	0	0	0	0	0	0
18	0	285	0	31	0	93	120	0	0	0
18	15	665	0	63	41	167	283	296	0	0
18	25	364	0	77	62	0	326	265	0	0
18	35	779	0	158	105	0	245	98	0	0
18	40	952	0	172	149	0	504	352	144	0
18	45	804	0	113	120	0	42	592	759	0
18	50	763	0	72	130	47	576	787	460	80

Appendix A. HPLC-Derived Phytoplankton Pigment Concentrations from NOSC 86 Cruise in the Greenland and Barents Seas: Station Data

Sta. No.	Depth	Chl a	Chl b	Chl c	Chlde a	Peridinin	Fuco	Hex	Diadino	Carotene
18	55	543	0	65	70	48	310	405	270	0
18	60	471	0	69	51	0	265	331	96	11
18	75	195	0	0	17	0	161	478	0	0
18	100	114	0	0	0	0	0	397	0	0
18	150	38	0	0	0	0	0	0	0	0
19	0	224	54	0	0	0	375	460	0	0
19	10	215	0	0	0	0	184	520	0	0
19	20	224	0	0	0	0	178	396	0	0
19	25	228	0	18	0	0	176	405	0	0
19	29	220	0	0	0	0	0	707	0	0
19	35	251	0	0	0	0	269	535	0	0
19	40	483	323	52	58	0	351	642	0	0
19	45	346	0	78	0	0	228	434	0	0
19	50	534	251	28	18	50	0	0	0	64
19	75	89	0	0	0	0	0	0	0	0
19	100	99	0	0	0	0	0	0	0	0
19	150	29	0	0	0	0	0	0	0	0
20	0	310	0	53	0	0	39	35	0	22
20	10	491	0	19	15	0	222	894	0	78
20	20	372	0	0	0	0	422	334	0	0
20	25	255	0	22	11	0	47	463	252	0
20	30	607	0	26	23	0	222	602	0	0
20	35	512	76	59	59	0	128	482	50	28
20	40	682	263	18	27	77	120	801	265	41
20	45	574	200	53	52	0	288	1056	0	76
20	50	394	265	35	32	0	34	148	14	0
20	75	37	0	0	0	0	0	0	0	0

Appendix B. HPLC-Derived Phytoplankton Pigment Concentrations from NOSC 86 Cruise in the Greenland and Barents Seas: Surface Data

Date	Time (GMT)	Chl a	Chl b	Chl c	Chlde a	Peridinin	Fuco	Hex	Diadino	Carotene
14 Aug	1847	444	0	240	134	0	471	281	0	67
15 Aug	0000	586	0	118	74	0	451	459	0	48
15 Aug	0600	190	0	35	17	0	139	291	0	32
15 Aug	1942	310	0	53	37	0	191	401	0	68
16 Aug	1610	631	0	146	0	0	900	0	592	0
16 Aug	2023	746	139	86	0	0	687	676	920	0
16 Aug	2300	377	0	0	0	0	608	590	0	136
17 Aug	0106	252	0	0	0	0	61	300	0	0
17 Aug	0320	372	0	27	0	0	932	0	0	0
17 Aug	0503	121	0	0	0	0	0	0	0	0
17 Aug	0615	184	0	0	0	0	0	0	0	0
17 Aug	1509	191	0	70	16	25	104	128	0	0
17 Aug	1600	354	0	88	0	24	349	0	0	29
17 Aug	1700	356	0	106	48	0	265	235	0	74
17 Aug	1800	163	0	16	0	0	89	64	0	21
17 Aug	1900	133	0	15	15	0	135	163	0	38
17 Aug	2000	84	0	0	0	0	62	100	0	0
18 Aug	0000	203	0	14	0	0	221	222	0	79
18 Aug	1800	82	0	0	0	0	0	0	0	0
19 Aug	0000	171	0	0	0	97	0	0	145	0
19 Aug	0600	71	0	0	0	0	0	0	0	0
19 Aug	1700	1543	193	179	181	0	263	904	570	40
19 Aug	2230	1478	184	212	156	81	448	1462	949	211
20 Aug	0600	363	0	146	0	0	222	701	230	15
20 Aug	1809	228	0	26	31	0	34	256	0	45
20 Aug	2305	111	0	0	0	0	153	407	0	0
21 Aug	1435	249	0	12	9	0	108	360	0	35
21 Aug	1800	210	0	22	0	0	103	215	0	32

Appendix C. HPLC-Derived Phytoplankton Pigment Concentrations from NOSC 87 Cruise in the Greenland Sea:
Station Data

Sta. No.	Depth	Chl a	Chl b	Chl c	Chlide a	Peridinin	Fuco	Hex	Diadino	Carotene
3	0	267	179	60	54	0	0	0	0	0
3	10	290	106	73	57	0	100	207	94	0
3	20	357	179	94	77	0	123	232	92	23
3	25	276	161	73	70	0	114	213	70	23
3	35	367	188	72	84	0	108	227	0	26
3	50	235	71	53	78	0	30	108	20	0
3	75	50	0	15	21	0	0	32	0	0
4	0	747	181	216	258	0	168	649	276	33
4	10	862	191	230	257	0	179	715	293	38
4	20	756	164	222	178	27	342	444	123	45
4	25	511	0	192	167	20	335	281	94	27
4	35	577	124	188	161	19	370	294	79	19
4	50	233	0	49	76	0	46	103	15	9
4	75	97	0	29	52	0	0	95	0	7
5	0	963	402	201	179	0	224	476	218	32
5	25	894	285	226	233	0	273	520	140	47
5	35	484	198	114	164	0	220	254	70	29
5	40	423	50	104	153	0	180	191	22	9
5	50	242	110	55	92	0	112	117	53	21
5	75	78	0	12	25	0	0	0	0	0
6	0	997	226	259	232	0	283	517	273	33
6	10	1052	156	243	198	0	299	532	272	51
6	20	1172	293	308	256	0	358	602	244	50
6	30	730	222	213	219	0	298	391	102	25
6	40	424	104	101	132	0	212	193	59	25
6	50	153	72	38	56	0	96	79	38	0
6	75	56	0	0	0	0	19	0	0	0
7	0	632	356	219	193	0	339	242	207	54
7	10	588	196	226	241	0	306	192	76	43
7	25	743	302	274	246	0	402	233	99	47
7	30	710	212	404	517	0	573	286	136	49
7	35	513	177	200	250	0	394	188	56	42
7	50	260	0	62	65	0	118	11	0	14
7	75	55	0	0	0	0	21	0	14	0
8	0	749	186	209	163	29	261	320	114	39
8	10	661	144	178	162	0	288	311	123	118
8	20	817	101	274	195	0	299	363	119	43
8	30	804	158	326	324	0	346	418	125	23
8	35	885	95	254	281	0	495	392	100	20
8	50	596	128	157	188	0	383	244	80	31
8	75	91	0	24	0	0	28	0	0	12
9	0	639	264	253	258	0	281	333	196	92
9	10	725	217	234	174	0	245	286	190	34
9	20	728	214	246	148	0	287	355	183	35
9	30	749	84	271	265	0	367	379	102	37
9	40	624	118	186	254	0	379	309	81	24
9	50	865	103	236	362	0	464	411	103	38
9	75	147	74	45	56	0	110	80	49	30

Appendix C. HPLC-Derived Phytoplankton Pigment Concentrations from NOSC 87 Cruise in the Greenland Sea:
Station Data

Sta. No.	Depth	Chl a	Chl b	Chl c	Chlide a	Peridinin	Fuco	Hex	Diadino	Carotene
10	0	1012	272	316	230	0	456	365	256	46
10	10	853	271	302	266	0	395	337	186	30
10	20	1216	305	305	177	0	458	399	208	39
10	30	1206	286	379	288	0	532	463	146	11
10	40	1186	308	281	313	20	474	571	91	28
10	50	1394	196	255	448	86	441	792	87	40
10	75	69	0	16	0	0	0	0	0	0
11	0	541	107	149	52	0	242	189	63	37
11	10	448	150	125	52	0	208	165	58	28
11	20	414	140	132	67	36	192	155	112	14
11	30	222	98	72	36	0	146	81	62	0
11	40	377	98	116	60	57	162	39	14	14
11	50	543	141	188	136	134	257	133	89	0
11	75	265	0	76	47	41	115	65	13	21
12	0	744	165	229	187	46	260	372	134	23
12	10	862	202	259	183	0	287	427	152	34
12	20	864	87	272	193	0	238	405	133	27
12	30	767	111	217	137	0	244	392	129	22
12	40	1015	115	224	319	55	406	543	123	41
12	50	240	0	58	73	22	163	126	44	0
12	75	58	0	0	11	0	0	0	0	0
13	0	956	202	298	209	68	374	365	160	27
13	10	921	217	288	205	55	336	393	174	37
13	20	923	214	288	184	51	369	397	169	27
13	30	682	206	222	174	53	299	337	123	25
13	40	309	98	85	81	39	207	109	48	24
13	50	274	158	48	52	42	169	104	0	23
13	75	45	0	12	0	42	0	0	0	0
14	0	1234	315	280	186	44	344	562	224	38
14	10	1402	248	386	302	31	415	673	61	30
14	20	1779	300	480	330	60	501	808	81	41
14	30	1636	68	439	407	66	431	738	52	24
14	40	1672	44	452	705	64	498	868	79	8
14	50	619	132	159	182	40	289	160	68	18
14	75	200	74	46	42	102	125	68	48	9
15	0	363	0	114	76	0	113	186	122	0
15	10	304	0	96	76	0	120	180	111	0
15	20	1176	104	518	338	42	480	594	99	20
15	30	911	104	320	381	0	475	588	64	13
15	40	566	142	209	239	26	444	232	43	0
15	50	190	74	56	62	0	153	64	0	0
15	75	554	76	193	170	0	272	285	100	0
16	0	510	175	122	85	0	208	130	0	40
16	10	988	179	227	134	0	379	150	176	53
16	17	1801	200	630	433	0	858	315	173	43
16	30	1060	149	241	198	51	519	188	68	31
16	40	1147	152	253	145	103	816	204	158	30
16	55	958	164	232	134	0	848	194	64	34

Appendix C. HPLC-Derived Phytoplankton Pigment Concentrations from NOSC 87 Cruise in the Greenland Sea:
Station Data

Sta. No.	Depth	Chl a	Chl b	Chl c	Chlide a	Peridinin	Fuco	Hex	Diatino	Carotene
16	75	157	82	37	43	0	135	42	34	0
17	0	423	0	169	154	0	163	310	135	0
17	10	568	190	185	152	0	180	373	94	0
17	20	508	88	180	142	0	183	347	136	0
17	30	580	0	211	176	0	196	392	64	28
17	40	532	0	180	205	0	204	316	41	0
17	50	282	0	93	117	32	162	79	10	35
17	75	46	0	0	0	0	0	0	0	0
18	0	466	158	142	89	35	161	250	146	30
18	10	461	0	154	90	26	148	276	131	20
18	20	406	85	156	111	17	128	270	77	6
18	30	437	128	166	143	23	145	319	82	19
18	40	568	139	185	222	34	193	418	77	12
18	50	746	183	219	299	90	291	356	88	21
18	75	84	0	25	16	0	29	0	0	0
19	0	882	232	271	233	0	288	572	221	23
19	10	1027	231	318	264	0	273	692	260	34
19	20	1096	121	309	242	0	355	783	81	0
19	30	973	258	271	327	26	390	466	38	0
19	40	936	191	246	366	48	400	489	80	30
19	50	537	69	80	96	15	228	188	39	11
19	75	49	0	0	0	0	28	0	0	0
20	0	670	115	274	230	0	360	356	223	18
20	10	615	158	222	184	0	308	338	216	15
20	20	1238	140	393	307	0	564	742	116	42
20	25	622	173	236	202	0	230	374	96	42
20	30	768	160	256	297	48	277	408	110	30
20	40	924	128	243	327	124	448	415	107	22
20	60	130	95	18	10	0	93	60	68	29
21	0	302	0	91	78	0	136	0	50	23
21	10	384	0	114	87	0	189	0	41	16
21	20	981	257	394	398	40	674	0	99	17
21	25	1605	205	721	825	112	1083	278	168	59
21	30	2605	148	831	1184	235	1255	1213	149	56
21	40	1149	197	275	385	120	494	321	91	38
21	60	356	0	85	191	14	162	176	19	0
22	0	483	129	150	118	0	277	108	124	34
22	10	427	188	109	102	0	253	132	127	0
22	15	463	173	131	100	0	309	0	132	26
22	20	560	204	161	128	0	344	144	128	29
22	30	573	95	243	257	0	427	113	0	0
22	40	762	102	281	372	56	530	0	27	31
22	60	537	36	173	298	16	301	63	24	20
23	0	395	0	125	112	0	232	127	100	17
23	10	363	0	115	86	0	186	0	78	0
23	20	789	140	277	260	0	646	193	143	58
23	25	668	184	306	285	0	557	150	96	25

Appendix C. HPLC-Derived Phytoplankton Pigment Concentrations from NOSC 87 Cruise in the Greenland Sea:
Station Data

Sta. No.	Depth	Chl a	Chl b	Chl c	Chlide a	Peridinin	Fuco	Hex	Diadino	Carotene
23	30	848	194	336	329	0	700	185	105	26
23	40	705	168	261	311	35	512	0	76	12
23	60	428	113	123	206	0	218	80	18	28
24	0	292	143	100	86	0	81	172	74	22
24	10	290	117	91	76	0	78	172	68	20
24	20	336	146	101	80	0	80	191	66	24
24	25	308	94	97	79	0	66	187	58	17
24	30	290	134	93	82	0	62	177	52	21
24	40	406	104	132	154	0	99	248	36	23
24	60	331	42	89	147	0	79	198	0	18
25	10	206	109	76	62	0	77	118	69	0
25	20	137	0	81	72	0	69	106	48	0
25	30	302	115	95	72	0	86	155	79	15
25	40	389	178	118	104	0	122	198	81	25
25	50	297	182	88	76	0	114	147	96	29
25	60	82	0	36	37	0	54	36	0	0
26	0	250	0	110	81	0	86	152	85	18
26	10	201	74	101	87	0	0	130	63	3
26	20	216	0	132	101	0	108	169	63	0
26	30	204	0	109	97	0	86	155	55	0
26	40	315	141	84	88	0	67	158	0	33
26	50	248	146	48	59	0	0	114	0	33
26	75	35	0	0	0	0	0	0	0	0
27	0	149	0	67	54	0	80	109	84	16
27	10	149	0	76	64	0	66	97	51	32
27	20	253	82	164	86	0	109	175	102	33
27	30	382	214	124	123	0	164	203	103	73
27	40	254	92	105	116	0	45	105	22	16
27	50	209	175	73	88	0	0	138	0	0
27	75	116	90	35	44	0	0	57	0	10

Appendix D. HPLC-Derived Phytoplankton Pigment Concentrations from NOSC 87 Cruise in the Greenland Sea:
Surface Data

Date	Time (GMT)	Chl a	Chl b	Chl c	Chl d + e	Peridinin	Fuco	Hex	Diadino	Carotene
2Aug	1900	710	167	197	200	0	155	518	233	34
2Aug	1935	1147	131	347	390	0	176	979	343	46
2Aug	1957	1303	179	352	428	0	162	1126	228	47
3Aug	1800	521	207	296	237	0	432	312	213	0
4Aug	0825	507	96	171	126	0	230	149	110	24
4Aug	1934	798	260	703	944	0	720	0	375	25
5Aug	0100	403	118	133	91	0	182	193	75	0
5Aug	2045	1011	289	428	422	0	533	424	277	37
5Aug	2223	691	132	213	164	0	298	264	167	25
6Aug	0026	0	0	0	0	0	0	0	0	0
6Aug	0100	493	219	120	93	0	154	273	132	0
6Aug	0230	502	183	137	101	0	194	258	139	20
6Aug	0430	404	135	122	91	0	182	225	62	14
6Aug	0515	353	56	118	60	0	162	20	64	0
6Aug	0606	335	95	88	43	0	168	97	66	22
6Aug	0646	244	0	76	31	0	125	80	28	0
6Aug	1830	217	72	65	46	0	81	88	23	15
7Aug	0120	381	79	134	84	15	154	144	87	21
7Aug	0121	626	210	194	180	48	257	347	104	25
7Aug	0122	910	301	274	216	29	358	401	132	34
7Aug	0123	556	74	179	119	60	252	265	118	32
7Aug	0124	850	80	269	179	77	370	384	168	36
7Aug	1312	1285	336	323	205	69	456	567	251	38
7Aug	1348	2768	1508	1125	569	0	1390	1123	984	222
9Aug	2203	926	199	334	234	37	384	495	219	32
10Aug	0502	518	53	302	188	0	251	270	126	30
10Aug	0615	617	187	296	119	0	370	226	186	50
10Aug	0339	1004	210	534	215	0	784	375	293	36
10Aug	0329	952	194	439	128	0	642	349	274	71
10Aug	0300	322	130	254	246	0	293	214	130	42

Approved for public release; distribution is unlimited.